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WATER RESOURCES STUDY PEMBINA RIVER
BASIN NORTH DAKOTA. STUDY OF POTENTIAL
NEEDS AND VALUE OF WATER FOR MUNICIPAL
INDUSTRIAL AND QUALITY CONTROL PURPOSES

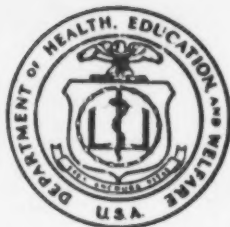
Public Health Service
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NOTES

WATER RESOURCES STUDY PEMBINA RIVER BASIN NORTH DAKOTA

Study of Potential Needs and Value of
Water for Municipal, Industrial, and
Quality Control Purposes



U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - St. Paul, Minnesota

MAY 1963

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WATER RESOURCES STUDY

PEMBINA RIVER BASIN

NORTH DAKOTA

Prepared for

DEPARTMENT OF THE ARMY

U. S. ARMY ENGINEER DISTRICT

St. Paul, Minnesota

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

MAY 1963

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I. INTRODUCTION

Authority

The Corps of Engineers, U. S. Army Engineer District, St. Paul, Minnesota, in a letter dated December 6, 1961, requested the U. S. Public Health Service, Region VI, Kansas City, Missouri, to conduct water supply and pollution control studies on the Pembina River of North Dakota.

The request and investigation were made in accordance with the Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare, dated November 4, 1958, and the Federal Water Pollution Control Act (Public Law 84-660) as amended by the Public Law 87-88.

Purpose and Scope

The purpose of the study was to establish the present and prospective needs for water supply and stream quality control in the United States' section of the Pembina River Basin. The United States Public Health Service was to determine the desirability of meeting these needs from storage in the Pembilier Dam and estimate the value of such storage.

The scope of this investigation covers the present, 50- and 100-year projections of the prospective water requirements for municipal and industrial water supply and for water quality control purposes.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in furnishing data for this report is gratefully acknowledged. Special thanks are extended to the North Dakota State Water Conservation Commission,

North Dakota State Department of Health, the Province of Manitoba Department of Health, the Province of Manitoba Department of Mines and Natural Resources, and to city officials and others in the area who supplied information relating to existing and expected water requirements.

II. SUMMARY AND CONCLUSIONS

Summary

1. This report deals with the portion of the Pembina River Study Area situated in the United States in the counties of Cavalier, Pembina, and Walsh in North Dakota.

2. The Park River Basin in Walsh County has been included, because of the possibility that the water from the proposed dam may be diverted to this basin.

3. Major municipalities in the study area are Walhalla, Niche, and Pembina located along the Pembina River, Cavalier located on the Tongue River, and Grafton and Park River located on the Park River. The major water using industries are the potato processing plants located at Grafton and Park River.

4. The major municipalities in the study area use the Pembina, Tongue, and Park Rivers as their sources of water. The major industries use highly mineralized ground water for processing. The river water can be treated to within the limits recommended by the Public Health Service Drinking Water Standards of 1962.

Conclusions

1. Population in the study area is expected to increase from 41,000 in 1960 to 60,000 by the year 2010 and 83,000 by 2060.

2. Projected municipal and industrial water needs in the study area in the year 2010 total about 3.2 mgd and in 2060 about 7.0 mgd. The Pembina Basin needs will be about 0.6 mgd in the year 2010 and 1.0 mgd by 2060 and the Tongue and Park Basins will need about 2.6 mgd by the year 2010 and 6.0

mgd by 2060.

3. Water supply needs in the study area can be met only partly from existing sources. It is expected that needs from the Pembilier Reservoir will be about 1.6 mgd (1,792 acre-feet) by the year 2010 and about 4.5 mgd (5,040 acre-feet) by 2060. The Pembina Basin needs from the Pembilier Reservoir are expected to be about 0.6 mgd by the year 2010 and 1.0 mgd by 2060 and the Tongue and Park River needs will be about 1.0 mgd by the year 2010 and 3.5 mgd by 2060.

4. The value of storage in the proposed Pembilier Reservoir to yield 4.5 mgd municipal and industrial water, using the cost of the most feasible alternative source, is estimated at \$121,000 annually or \$24.20 per acre-foot.

5. Pending further studies of the Red River of the North, the need for streamflow regulation is limited to the Pembina River Basin. The flow requirements for water quality control in the Pembina River Basin to assimilate the treated present and future waste discharges are approximately 0.7 cfs at the present time and are expected to be 1.2 cfs by the year 2010 and 1.7 cfs by 2060. Recognition should be given to the potential use of the Pembilier Reservoir for streamflow regulation for quality control of the Red River of the North.

6. The value of storage of water in the Pembilier Reservoir for water quality control may be estimated as equal to the total cost of an impoundment to produce the amount of water needed in the Pembina River and the Red River of the North. A study of the water needs in the Red River of the North is being conducted by the U. S. Public Health Service.

III. DESCRIPTION OF PROJECT

Purpose

The purpose of the proposed Pembilier Dam is to provide flood control and water for irrigation, water supply, and other related uses.

Location

The proposed Pembilier Dam is to be located on the Pembina River at the Cavalier-Pembina County line in North Dakota, T.162 N., R.56 and 57 W., about 94.3 miles above the river mouth. The river rises in southwestern Manitoba and north-central North Dakota, flows generally in an easterly direction and crosses the international boundary from Canada into North Dakota a little over midway in its course. It then flows parallel to the border until it joins the Red River of the North about two miles south of the boundary at Pembina, North Dakota. (See vicinity map at back of report.)

Hydrology

The flow in the Pembina River varies from no flow to a maximum of 20,400 cfs (cubic feet per second) at the gaging station about 3 miles above the damsite near Walhalla, North Dakota, (see Exhibit No. 1 in the Appendix). Runoff attains its highest rate from snowmelt in the spring after winter winds sweep prairie snow into the tributary coulees. Rainfall rarely occurs with sufficient intensity to produce more than moderate stages in the river.

Water Quality

The quality of the water above the damsite shows considerable variation in turbidity, suspended solids, hardness, and sulfates. (See Exhibits Nos. 3 and 4 in the Appendix.) However, those municipalities using the Pembina River below the damsite are producing a treated water that is within the limits recommended by the Public Health Service Drinking Water Standards of 1962. The quality of the water in the river below the proposed Pembilier Dam should be improved by storage.

Pertinent Data

The proposed dam would be about 170 feet in height and would have a 20 foot wide crest at elevations of 1,138.0. At minimum conservation-pool level, elevation 1,005, a storage volume of 10,000 acre-feet would be provided for sediment storage and recreational use. About 290,000 acre-feet of storage would be occupied at spillway crest, elevation 1,116.0, and approximately 388,000 acre-feet would be utilized in passage of a spillway design flood which would attain elevation 1,133.0.

Of the total storage of 290,000 acre-feet available at spillway level, about 10,000 acre-feet would be for minimum conservation pool; 130,000 acre-feet would be between elevation 1,005 and 1,080 for water supply and irrigation; 70,000 acre-feet between elevation 1,080 and 1,100 would be allocated to use for flood control, water supply and irrigation; and the remaining storage of about 80,000 acre-feet would be for flood control only.

The International Pembina River Engineering Committee in compliance with a request by the International Joint Commission to the International

Souris-Red River Engineering Board is conducting a joint investigation by agencies in Canada and the United States to develop the water resources of the river. The Committee has allocated 5,000 acre-feet of conservation storage in the proposed reservoir for municipal and industrial use in North Dakota and 5,000 acre-feet for use in Canada. 8/

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The study area includes the counties of Cavalier, Pembina, and Walsh in the northeast corner of North Dakota. The river crosses the northeast corner of Cavalier and flows across the northern half of Pembina County. The county of Walsh has been included because of the possibility that the water from the proposed dam may be diverted to the Park River Basin. (See area map at back of report. This map does not include Walsh County which is located just south of Pembina County.)

General Features

The western section of the Pembina River Basin is a rolling prairie plateau with flat, open terrains and numerous closed drainage basins. However, below the international boundary the low lying Pembina escarpments separate this section from the level Red River Valley plains of the eastern section. Through the escarpment the Pembina River flows in a canyon-like valley 150 to 450 feet below the prairie plateau. The width of the valley varies from 3,000 to 8,000 feet. As the stream emerges from the escarpment the valley gradually loses its identity. For the remainder of its course, the river twists across the level valley plains to its confluence with the Red River of the North.

The mean annual temperature for the basin is 39°F , with mean monthly temperature variations of -14.5°F to 72.3°F . Extremes of -50°F and 100°F have been recorded. The average annual precipitation in the Pembina watershed is about 18 inches and the growing season is about 100 days.

The largest community in the study area is Grafton, located in the Park River Basin, with a population of 5,885 in 1960. Other communities in the study area, in order of their 1960 population, are: Langdon (2,151), Park River (1,813), Walhalla (1,432), Cavalier (1,423), Drayton (940), Minto (642), Pembina (625), Neche (545), Adams (360), and Osnabrock (289).

The industries in the area are mainly in the food and kindred products category. A new sugar beet processing plant is to be located at Drayton on the Red River of the North. 28/

V. ECONOMY

Present

Table No. V-1 shows that the study area has had an 18 percent population increase in the last 50 years, from 49,899 in 1910 to 41,027 persons in 1960. 17,18,19/ Grafton, the only community in the study area which meets the Bureau of Census urban area definition, had a population of 5,885 in 1960. 17/

Table No. V-1

Population Trends for the Pembina River Study Area 17,18,19/

	<u>1910</u>	<u>1920</u>	<u>1930</u>	<u>1940</u>	<u>1950</u>	<u>1960</u>
Rural*	49,899	47,298	46,222	46,271	39,788	35,142
Urban*	-	<u>2,512</u>	<u>3,136</u>	<u>4,070</u>	<u>4,901</u>	<u>5,885</u>
TOTAL	49,899	49,810	49,358	50,341	44,689	41,027

*U. S. Bureau of Census definition.

The economy of this area is dependent primarily upon services and agriculture. In 1960, of the 12,355 persons employed in the study area, over 98 percent was employed in these categories, 20/ and the remaining two percent was employed in the manufacturing category. Table No. V-2 depicts employment data for the Pembina River Study Area.

Agricultural employment in the study area has decreased from 8,586 in 1950 to 5,562 in 1960. 20,21/ During this decade the number of farms has also decreased from 5,548 to 4,769. 22,23/ However, agriculture remains one of the leading contributors to the economy by employing 43 percent of the total labor force in 1960. With technological improvements and farm consolidations, the value of farm products has increased with less farms and employment. This increase was from \$42.4 million in 1950

to \$54.9 million in 1959 (adjusted to the 1954 value of the dollar). 22,23,24/

Table No. V-3 depicts agricultural data for the Pembina River Study Area.

Table No. V-2

The Number and Percentage of the Labor Force 20,21/
By Major Classification in the Pembina River Study Area

1940 - 1950 - 1960

	<u>1940</u>		<u>1950</u>		<u>1960</u>	
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>
Farm	9,827	55.0	8,586	54.0	5,562	43.0
Mining	2	-	4	-	4	-
Manufacturing	144	1.0	157	1.0	305	2.0
TOTAL BASIC	9,973	56.0	8,747	55.0	5,871	45.0
TOTAL SERVICE	6,552	36.0	6,701	42.0	6,484	50.0
Unemployed	1,468	8.0	513	3.0	624	5.0
TOTAL LABOR FORCE	17,993	100.0	15,961	100.0	12,979	100.0

Table No. V-3

Agricultural Data

Pembina River Study Area 22,23,24/

1949 - 1954 - 1959

	<u>No. Farms</u>	<u>Acres of Cropland Harvested</u>	<u>Value of all Farm Products Sold*</u> (Millions of Dollars)
1949	5,548	1,480	42.4
1954	5,397	1,552	42.4
1959	4,769	1,458	54.9

*Adjusted to the 1954 value of the dollar.

Manufacturing has played a minor role in the area. In 1960, there were 305 employees in the manufacturing category; approximately 80 percent was employed in the food and kindred products category. ^{20/}

Minerals of economic importance in the area are limited to sand and gravel and stone. The values of minerals extracted ranged from approximately \$400 thousand to about \$700 thousand annually over the last three years. There are no other known minerals of economic importance available in the study area. ^{25,26/}

Future

Fertile agriculture land and increased agricultural production with the presence of a dependable water supply from the Pembilier Dam and Reservoir is expected to stimulate economic activity in the tri-county study area. Although agriculture should continue as the primary basic economic activity and employ a large part of the basic labor force, manufacturing should increase and play a more important role in the future. The primary manufacturing employment should be in the food and kindred products and fabricating metal, machinery, and other durables categories. However, the service establishments, supporting the basic industries, should absorb the major portion of the labor force. Projected employment data is presented in Table No. V-4.

The study area population is assumed to increase at the same rate as the State of North Dakota. ^{27/} At this rate, the study area should reach 60,000 by the year 2010 and 83,000 by 2060. Several communities in the study area are expected to be urban in the future. The urban popula-

tion is expected to reach 29,000 by the year 2010 and 55,000 by 2060. Population projections for the State of North Dakota and the study area are shown in Figure 1.

Table No. V-4
Projected Employment of Labor Force
Pembina River Study Area

	<u>2010 - 2060</u>			
	<u>2010</u>		<u>2060</u>	
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>
Farm	4,500	23	4,000	15
Mining	50	-	100	-
Manufacturing	2,400	13	3,400	13
TOTAL BASIC	6,950	36	7,500	28
TOTAL SERVICE	11,500	60	18,000	67
Unemployed	750	4	1,000	5
TOTAL LABOR FORCE	19,200	100	26,500	100

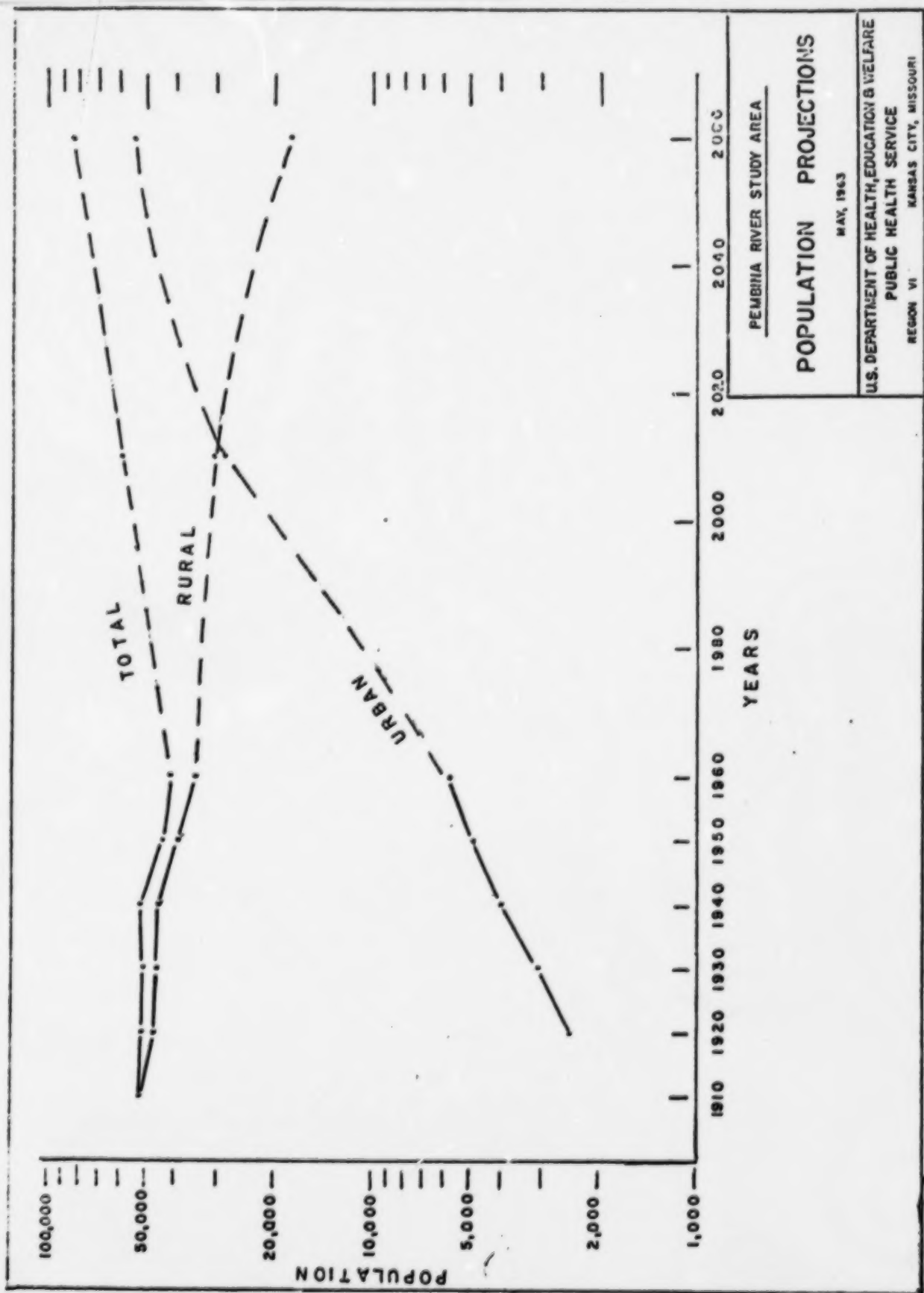


FIGURE V-

VI. HYDROLOGY

Surface Water

The mean annual precipitation in the Pembina Watershed is approximately 18 inches. Very little of this appears as runoff because of the flat, open terrain which increases the amount of seepage and evaporation. Runoff attains its highest rate from snowmelt in spring after winter winds sweep prairie snow into the tributary coulees. Rainfall rarely occurs with sufficient intensity to produce more than moderate stages in the river. The historical streamflows data for the Pembina and Park Rivers are shown in Exhibit No. 1 in the Appendix. ^{1,2/}

Exhibit No. 2 in the Appendix shows duration curves of mean monthly flows at Neche on the Pembina River and at Grafton on the Park River. Fifty percent of the time the flow at Grafton is less than 1 cfs and about 70 percent of the time it is less than 5.0 cfs. At Neche the flow is less than 1 cfs about 15 percent of the time and less than 5 cfs about 25 percent of the time.

The average annual discharges of the Pembina River at Neche and the Park River at Grafton is shown in Table No. VI-1.

Table No. VI-1

Comparison of Average Annual Discharges of Pembina and Park Rivers ^{2/}

	Years of Record	Average Discharge	
		Cubic Feet/Second	Acre-Feet
Pembina River at Neche	53	162	117,300
Park River at Grafton	30	48.1	34,820

The Department of Health and the Department of Mines and Natural Resources of the Province of Manitoba have been testing the Pembina River for quality at various points in Canada. (See map at back of report.) Exhibit No. 3 in the Appendix gives the results of the tests that were run from June 2 to August 2, 1962. Exhibit No. 4 consolidates the results of 15 samples taken from the Pembina River near Windygates, Manitoba, from September 6, 1960 to May 4, 1962. The report "Pembina River Survey, 1962," ^{14/} states the following:

"The water quality of samples taken near Windygates, Manitoba, shows considerable variation in turbidity, suspended solids, hardness, and sulphate, which would complicate treatment. These factors, however, would all be improved by a watercourse controlled by a system of dams which would even water flows."

"The oxygen relationship (D.O. and B.O.D.) indicate an extremely poor environment for aquatic life. The oxygen saturation varying from zero to supersaturation, and the B.O.D. rising as high as 15 ppm. These factors indicate heavy algal growths which pulse in their growth patterns. This could be greatly improved by the increase of water depths which would accompany dam construction."

Ground Water

The Red River Valley, located below the Pembilier Dam site, has very little ground water of good quality. Limited quantity of ground water occurs in recent alluvium, Pleistocene glacial drift, and bedrock. Water of the best quality is found in the aquifers in the beach or shore de-

posits of glacial Lake Agassiz, which is the present Red River Valley.

Three investigations have been made of ground water in the study area. 12,15,16/ Each of these investigations has disclosed a limited quantity of ground water. The study in the vicinity of Waihalla 12/ disclosed the possibility of aquifers which would supply some water. However, the chemical analysis of the water from the test holes indicates that the water exceeds the levels recommended by the Public Health Service Drinking Water Standards for 1962 for iron, sulfates or dissolved solids. Chemical analysis of the water from this area is shown in Exhibit No. 5 in the Appendix. The investigation near Hoople, North Dakota, 16/ disclosed that the water had dissolved solids content greater than 2,000 ppm and the quantity was not capable of supplying Hoople (1960 population, 334). The study made near Neche 15/ reported sand in the alluvial deposits of the Pembina Valley in limited quantity and water from the bedrock with high mineralization. Ground water is available in the bedrock from the Dakota sandstone of the Cretaceous age. However, this water exceeds the recommended standards of the Public Health Service Drinking Water Standards of 1962. The total quantity of ground water which may be safely developed perennially from any given area can be determined only by special investigations.

VII. MUNICIPAL AND INDUSTRIAL WATER SUPPLY NEEDS

Present

Data on municipal water systems in the Pembina River Study Area are shown in Exhibit No. 6 of the Appendix. The largest municipality in the study area is Grafton, which had a 1960 population of 5,885. Grafton is located on the Park River and at the present time is receiving its water from the Homme Reservoir. The City of Park River (1960 population, 1,813) is also utilizing the Homme Reservoir as its source of municipal water. The storage of the Homme Reservoir is approximately 3,550 acre-feet, but effective storage is only about 2,130 acre-feet. ^{6/} Homme Reservoir is located on the South Branch of Park River about 2 miles west of Park River, North Dakota. The Homme Dam was completed in October 1950. The reservoir is operated for flood control, water supply, and pollution abatement during low-flow periods. ^{2/} Both Grafton and Park River originally used wells that were mineralized and the water did not meet the recommended Public Health Service Drinking Water Standards (see Exhibit No. 7 in the Appendix). At the present time several industries in the area use the highly mineralized well water for processing and use the municipal water only for the final process.

The three municipalities with water supplies located in the Pembina River Basin, below the Pembilier Damsite, are Walhalla, Neche, and Pembina, North Dakota. Walhalla, the largest of the three, obtains its water from shallow wells located near the river. Neche and Pembina use the river as their source of water. Neche, the smallest of the three municipalities, treats the largest amount of water. About three-fourths of its plant's

production is to supply the municipalities of Altona and Gretna, which are located north of the international boundary in Canada. Pembina, North Dakota, is located at the junction of the Pembina River with the Red River of the North, but uses the Pembina River as its source of water.

Cavalier, located on the Tongue River, obtains its water from wells and the Tongue River. Drayton is located on the Red River of the North and obtains its water from that river. Adams, Langdon, Minto, and Osnabrock obtain their water from ground sources. (Exhibit No. 6 in the Appendix.)

Prospective

The two municipalities located on the Pembina River that obtain their supply direct from the stream are Natchez and Pembina. Walhalla has wells but may use the water direct from the Pembina River in the future. Since no large industrial water users are expected in this section of the study area, future water requirements have been determined on a per capita basis, using the projected urban population as a base. This per capita factor reflects public, commercial, and domestic users. The present per capita water usage rate is expected to rise as modern household units, such as automatic washing machines and garbage disposals, become more prevalent. This per capita water usage rate also includes an increase in the number of agriculture-associated industries which will not use excessive quantities of water.

At the present time, these three municipalities use approximately 50 gallons per capita per day and total 0.13 million gallons per day.

This does not include the water pumped from Neche to Canada. By the year 2010 the per capita use is expected to be 145 gpcd and by 2060 is expected to reach 175 gpcd. Using the expected rates, the total municipal and industrial water usage in this section is expected to be approximately 0.6 mgd by the year 2010 and 1.0 mgd by 2060.

Consideration was given to the diversion of water from the Pembina River to its sub-basin, the Tongue River, and the Park River, located south of the Pembina-Tongue River in Walsh County, North Dakota. Although the problem of water supply in the Park and Tongue Rivers Basins is not critical at the present time, the diversion of the Pembina River water should be considered due to the expected population growth of the area. This diversion would benefit Cavalier and Grafton, which have municipal water supplies and new water supplies at Crystal, St. Thomas, and Hoople who have requested the North Dakota Water Conservation Commission to aid them in obtaining a source of water. ^{6/}

At the present time about 9,000 persons in the Tongue and Park River Basins could be supplied from the Pembilier Reservoir. Present rate of use is about 85 gpcd. It is expected that this per capita use will increase to 145 gpcd in 2010 and 175 gpcd in 2060. It is expected that the large industrial water users will continue to use the highly mineralized ground water for all their processes except the finishing operation.

By the year 2010 the population of this section of the study area, is expected to increase to 18,000 and require approximately 2.6 mgd. By the year 2060 the population is expected to increase to 34,000 and re-

quire approximately 6 mgd. Some of this water will be from the Tongue, Park River and ground sources, but it is expected that water from the Pembilier Reservoir at the rate of 1.0 mgd will be needed by the year 2010 and 3.5 mgd by 2060.

It is expected that the Red River of the North will continue to be used by Drayton and other municipalities within ready access to this river. Drayton's water supply needs will be included in the Red River of the North study. Langdon and other municipalities in the study area are expected to continue to obtain their water supplies from the ground and surface sources in their general area.

The total projected water needs in the study area will be about 3.2 mgd in the year 2010 and 7.0 mgd in 2060. Of this total it is expected that the needs from the proposed Pembilier Reservoir will be about 1.6 mgd (1,792 acre-feet) by the year 2010 and 4.5 mgd (5,040 acre-feet) by 2060.

Value of Storage

The value of storage was estimated by considering the most feasible alternative source available in lieu of the proposed project. Since ground water supplies, except for limited quantities, are highly mineralized, and the damsites in the Park River Basin are limited, the Pembina River offers the only source of adequate water. Water to meet the 5,040 acre-feet needed for water supply in the study area could be assured by construction and operation of a 15,000 acre-foot reservoir at an estimated first cost of \$2,500,000. Average annual charges, based on a 4% interest

rate for a 50-year-repayment period and including operation and maintenance cost, are estimated at \$121,000. With the annual delivery of 5,000 acre-feet, the cost would be \$24.20 per acre-foot.

VIII. STREAMFLOW REGULATION FOR QUALITY CONTROL

Present Uses

With the exception of Walhalla and Drayton, all the municipalities in the Pembina River Study area discharge their sewage into waste stabilization lagoons. (Exhibit No. 8 in the Appendix.) Walhalla discharges raw sewage into the Pembina River and Drayton discharges into the Red River of the North. Walhalla is, at the present time, considering the installation of a stabilization lagoon to treat their waste.

The Pembina River supports limited sport fishing. Most of the fishing is during and directly after the period of spring runoff when the fish are moving up from the Red River of the North. During the balance of the fishing season the reduced flows largely limit the fishing to the pools. No other recreational use of the river is known.

The river is not used for irrigation or power but has a limited use for stock watering.

Prospective Uses

Future sewage and waste pollution from the municipalities and industries located along the Pembina River is expected to increase at approximately the same rate as the population increases. It is expected that each municipality and industry located in this area will provide adequate waste treatment facilities. It is also expected that the discharge from the proposed Pembilier Dam will be so constructed that the water discharged to the river will have a minimum of 4 ppm of dissolved oxygen.

It is proposed that water from the Pembilier Reservoir will be used for irrigation. The return irrigation water is not expected to be sufficient

in the Pembina River to create a problem. However, since most of the land to be irrigated drains to the Red River of the North, there may be a problem in this river. Also farm operation, with the use of chemicals, such as synthetic fertilizers and pesticides, may have detrimental effects on the quality of streams receiving drainage runoff. The farmers of the area should be cautioned about the use of such chemicals.

Recognition should be given to the potential use of the Pembilier Reservoir water for flow augmentation of the Red River of the North. A study of the water needs in the Red River of the North is at the present time being conducted by the U. S. Public Health Service which should reflect the future flows for quality control.

There has been no proposed use of the Pembilier Dam for power production.

The water from the proposed reservoir may be used for a fish hatchery located below the dam. The North Dakota State Game and Fish Department has indicated an interest in such a hatchery.^{8/} The water from the reservoir for this purpose should have a minimum of 4 ppm of dissolved oxygen. With flow in the Pembina River below the dam the fishing and other recreational uses should increase.

The flow requirements for water quality control in the Pembina River to assimilate the treated present and future waste discharges is approximately 0.7 cfs at the present time, 1.2 cfs by the year 2010 and 1.7 cfs by 2060.

Value of Storage

Pending further studies of the Red River of the North, the need for streamflow regulation is limited to the Pembina River Basin. The amount is estimated to be approximately 0.7 cfs at the present time, 1.2 cfs by the year 2010 and 1.7 cfs by 2060. The needs for streamflow regulation in the Red River of the North will probably increase in the near future with the new sugar beet plant at Drayton and other industrial developments. The value of storage of water in the Pembilier Dam may be estimated as equal to the total cost of an impoundment to produce the amount of water needs in the Pembina River and the Red River of the North.

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X. APPENDIX

Exhibit No. 1

Historical Streamflows in the Pembina River Study Area 1, 2/

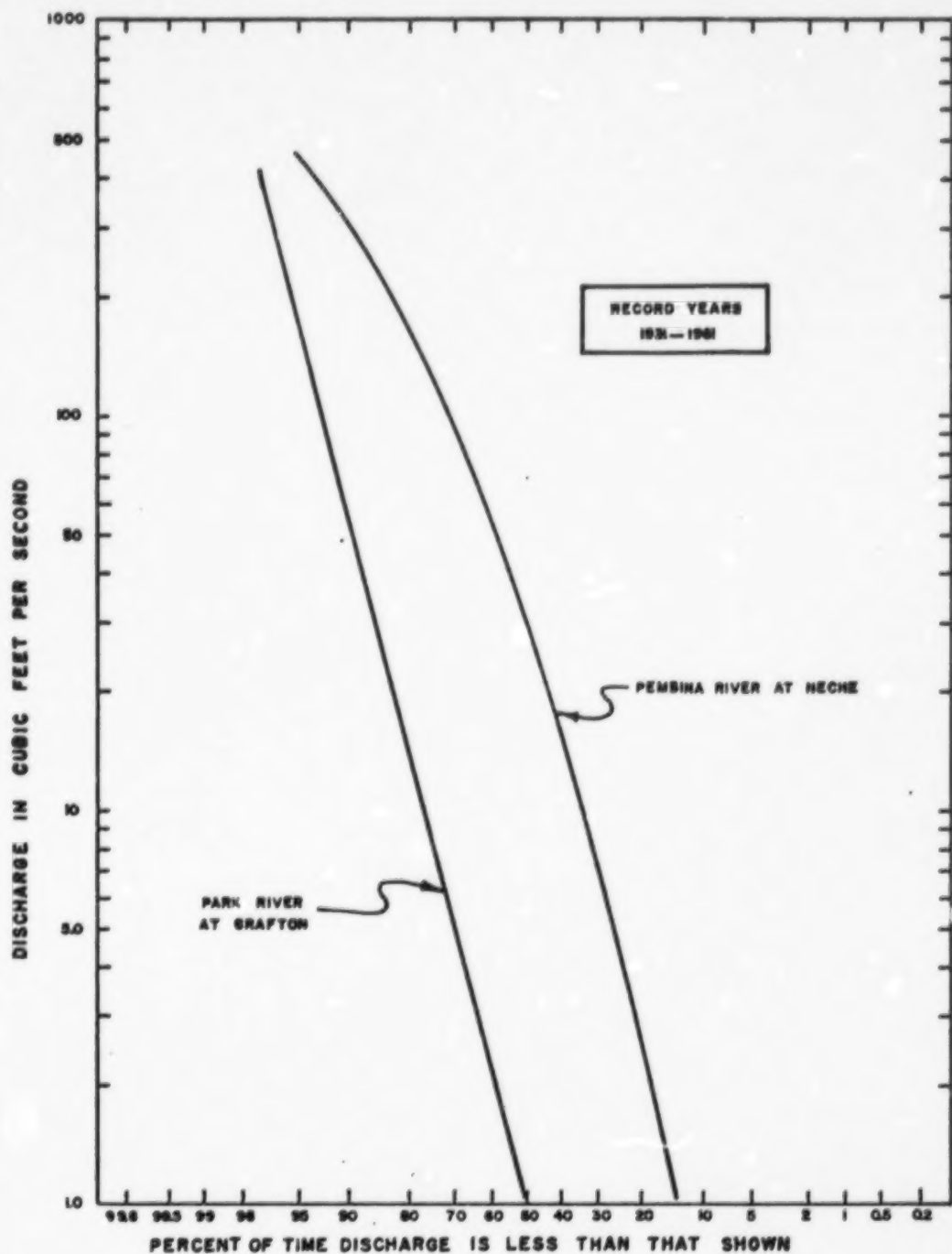
Station	Gage Location	Drainage Area Above Station Square Miles	Years of Record	Flow Cubic Feet per Second		
				Maximum	Minimum	Average
Pembina River near Manitou, Manitoba	On bridge 7 M. south of Manitou	2,090	43	5,030	0	-
Pembina near Kaleida, Manitoba	At bridge 4½ M. south of Kaleida	2,820	4	2,660	0	-
Little Pembina River near Walhalla, North Dakota	Right bank 25 ft upstream from county bridge 3½ M. above mouth and 6 M. southwest of Walhalla	182	5	4,160	0	-
Pembina near Walhalla, North Dakota	Left bank 1½ M. downstream from Little Pembina River and 3½ M. southwest of Walhalla	3,280	22	20,400	0	203
Pembina River near Neche, North Dakota	Right bank, 4 blocks east of re- located State Highway 18 at north edge of Neche	3,360	53	10,700	0	162
Ierzog Creek, Tongue River near Concrete, N. Dakota	Right bank 1½ M. northeast of Concrete and 1½ M. upstream from mouth	18.9	7	260	0	2.41
Tongue River at Akra, North Dakota	Right bank, 0.6 M. east of Akra and 4.2 M. west of Cavalier	162	10	11,800	0	15.1
Tongue at Cavalier, North Dakota	At dam, ½ M. upstream from State Highway 5 at Cavalier	153	13	11,800	0	21.3

Exhibit No. 1. (Cont.)

Historical Streamflows in the Pembina River Study Area 1.2/

Station	Gage location	Drainage Area Above Station Square Miles	Years of Record	Flow Cubic Feet per Second	
				Maximum	Minimum Average
Longue near Pembina, North Dakota	At C.C.C. dam $3\frac{1}{2}$ M. upstream from confluence with Pembina River and 5 M. southwest of Pembina	460	3	1,450	0
South Fork Pembina River below Homme Dam, North Dakota	On right bank $\frac{1}{2}$ M. downstream from Homme Dam and 2 M. west of Park River, North Dakota	226	12	13,000	0 23.9
Heart Creek at Mountain, North Dakota	On right bank on State High- way 32 and 0.7 miles south of Mountain	16.9	7	570	0 2.02
Pembina River at Grafton, North Dakota	On right bank 30 ft upstream from Wakeman Avenue bridge in Grafton and 3.5 M. downstream from North Fork	695	30	12,600	0 48.1

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PEMBINA RIVER STUDY

DURATION CURVE OF MEAN
MONTHLY RIVER FLOW

APRIL 1963

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MISSOURI

EXHIBIT NO. 2

Exhibit No. 3

Analysis of Pembina River Water (ppm)*

Province of Manitoba

June 20 - August 2, 1962

Total Hardness (as CaCO ₃) Mean	Range	Sodium (as Na)		Iron (as Fe)		Chlorides (as Cl)		pH		Alkalinity (Total)		Dissolved Oxygen		Dissolved Oxygen		BOD (5-day)		No. of Samples
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	
292	280-320	54	34-76	.18	.12-.27	16	7-23	7.7	7.4-8.0	276	270-312	4.9	3.9-6.4	55	43-73	2.1	1.7-2.4	4
431	316-476	62	47-68	.19	.12-.24	10	5-13	7.9	7.6-8.0	284	220-310	7.6	6.6-8.6	80	70-86	2.1	1.4-3.2	4
270	260-288	56	54-59	.19	.12-.27	13	12-14	8.4	8.2-8.6	165	148-180	5.7	5.0-6.7	63	52-76	1.6	1.2-1.9	4
251	236-276	38	37-39	.16	.10-.23	9	9-10	8.1	7.5-8.6	152	136-176	4.8	0 -10.2	53	0-113	5.6	4.6-15.5	4
246	232-268	37	35-40	.15	.12-.18	10	10	7.6	7.3-8.0	177	164-188	5.0	0.6-9.7	55	7-108	5.8	2.9-8.0	4
252	236-272	38	36-41	.22	.10-.30	9	8-10	8.2	8.0-8.4	185	175-202	7.3	6.3-8.4	82	79-91	1.8	1.6-2.3	4
267	260-280	41	39-43	.21	.10-.28	10	10	8.2	8.0-8.3	193	186-196	8.5	7.8-8.7	97	91-101	2.1	1.8-2.6	4

*" Department of Health, and Mines, and Natural Resources of the Province of Manitoba, 1962.

Exhibit No. 3

Analysis of Pembina River Water (ppm)*

Province of Manitoba

June 20 - August 2, 1962

Station	Total Solids		Total Hardness		Sodium		Iron		Chlorides		pH		Alkalinity		Dissolved	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Ninette	536	420-638	292	280-320	54	34-76	.18	.12-.27	16	7-23	7.7	7.4-8.0	276	270-312	4.9	3.9-6.4
South of Pembina Lake	714	576-820	411	316-476	62	47-68	.19	.12-.24	10	5-13	7.9	7.6-8.0	284	220-310	7.6	6.6-8.6
Neelin	540	434-692	270	260-288	56	54-59	.19	.12-.27	13	12-14	8.4	8.2-8.6	165	148-180	5.7	5.0-6.7
Below Rock Lake	431	368-474	251	236-276	38	37-39	.16	.10-.23	9	9-10	8.1	7.5-8.6	152	136-176	4.8	0 -10.2
Below Swan Lake	416	320-492	246	232-268	37	35-40	.15	.12-.18	10	10	7.6	7.3-8.0	177	164-188	5.0	0.6-9.7
LaRiviere	419	320-470	252	236-272	38	36-41	.22	.10-.30	9	8-10	8.2	8.0-8.4	185	175-202	7.3	6.3-8.4
North of Windygates	464	410-498	267	260-280	41	39-43	.21	.10-.28	10	10	8.2	8.0-8.3	193	186-196	8.5	7.8-8.7

*Pembina River Survey: Department of Health, and Mines, and Natural Resources of the Province of Manitoba, 1962.

Exhibit No. 4

Analysis of Pembina River Water Samples (ppm)*

Near Windygates, Manitoba from Bridge near U.S. Border

Total Hardness (as CaCO ₃)		Copper (as Cu)		Iron (as Fe)		Chlorides (as Cl)		pH		Zinc (as Zn)		Sulphate (as SO ₄)		Fluoride (as F)		Nitrate (as NO ₃)	
Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
341	111-566	0	0	.29	.08-1.1	16	3-30	8.0	7.4-8.4	0	0	208	48-403	0.42	.3-.52	1.6	0-8.0

Windygates, Manitoba," Department of Mines, and Technical Surveys, Mines Branch, Mineral Processing Division,
Ottawa, Ontario, September 6, 1960-May 4, 1962.

Exhibit No. 4

Analysis of Pembina River Water Samples (ppm)*

Near Windygates, Manitoba from Bridge near U.S. Border

Manganese (as Mn)	Total Solids		Total Hardness (as CaCO ₃)		Copper (as Cu)		Iron (as Fe)		Chlorides (as Cl)		pH		Zinc (as Zn)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
.22 .05-.6	533	369-664	341	111-566	0	0	.29	.08-1.1	16	3-30	8.0	7.4-8.4	0	0

Number of Samples - 15

*"Analysis of Water Samples, Windygates, Manitoba," Department of Mines, and Technical Surveys, Mines Branch, Mineral Industrial Water Section, Ottawa, Ontario, September 6, 1960-May 4, 1962.

Exhibit No. 5 .

Chemical Analysis of Ground WaterMuhalla, North Dakota
(Results in parts per million)

Item	1971			1973
	1971	1972	1973	
Iron (Fe)	0.6	0.6	0.6	0.5
Calcium (Ca)	107	107	102	102
Magnesium (Mg)	43	31	31	29
Sodium (Na)	35	44	32	10
Potassium (K)	11	7	9	4
Bicarbonates (HCO_3)	350	333	432	350
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	356	103	233	81
Chloride (Cl)	34	14	37	0
Fluoride (F)	0.3	0.3	0.3	0.3
Nitrate (NO_3)	0.5	0.1	1.1	0.1
Boron (B)	0.0	0.2	0.2	0.1
Hardness (CaCO_3)	556	339	367	374
Dissolved Solids	953	573	563	496
Depth (feet)	73	31	32	84

Widolphson, D. G., "Test Drilling in the Muhalla Area Pembina County, North Dakota," U. S. Geological Survey and North Dakota Water Conservation Commission, Open File Report, Table 1, (October 1950).

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Exhibit No. 6

Municipal Water SuppliesPembina River Study Area 5/

Municipality	1960 Population	Source	Capacity		Average Plant Ou (Million Gallons/
			Surface (Million Gallons/Day)	Ground	
Adams	360	Well		0.110	0.018
Cavalier	1,423	Wells & Tongue River	**	0.288	0.120
Drayton	940	Red River	UNL		0.060
Grafton	5,885	Park River	3.000		0.500
Langdon	2,151	Infiltration Gallery		0.570	0.112
Minto	642	Well		0.100	0.040
Neshe	545	Pembina River	0.710		0.120*
Osnabrock	289	2 wells		0.125	0.020
Park River	1,813	Wells & Park River		0.432	0.140
Pembina	625	Pembina River	0.190		0.050
Walhalla	1,432	Wells		0.260	0.050

*Neshe's plant supplies about 3/4 of its output of water to Gretna and Altona in Canada.

**Information unknown

UNL - Unlimited supply

Exhibit No. 7

Chemical Analyses of the Municipal Water Supply

Pembina River Study Area 3/

Municipality	Source	Total Dissolved Solids ppm	Total Hardness As CaCO ₃ ppm	Iron (Fe) ppm	Chlorides (Cl) ppm	Sulfates (SO ₄) ppm	Nitrates (NO ₃) ppm
Cavaller	Tongue River and wells	150-768**	116-665	Trace-5.3**	9-22	0-66	...
Drayton	Red River	343	287	1.4**	15	30	Trace
Grafton*	Wells	5767**	220	0.9**	1880**	740**	217**
Langdon	Infiltration Gallery	345	152	0.1	48	34	2.1
Minto	Well	850**	560	0.2	72	65	2.1
Park River*	Wells	752**	440	...	20	198	Trace
Pembina	Pembina River	409	72	Trace	34	174	2.2
Walhalla	Wells	620**	390	0.5**	18	157	11.0

ppm - parts per million

... - Information unknown

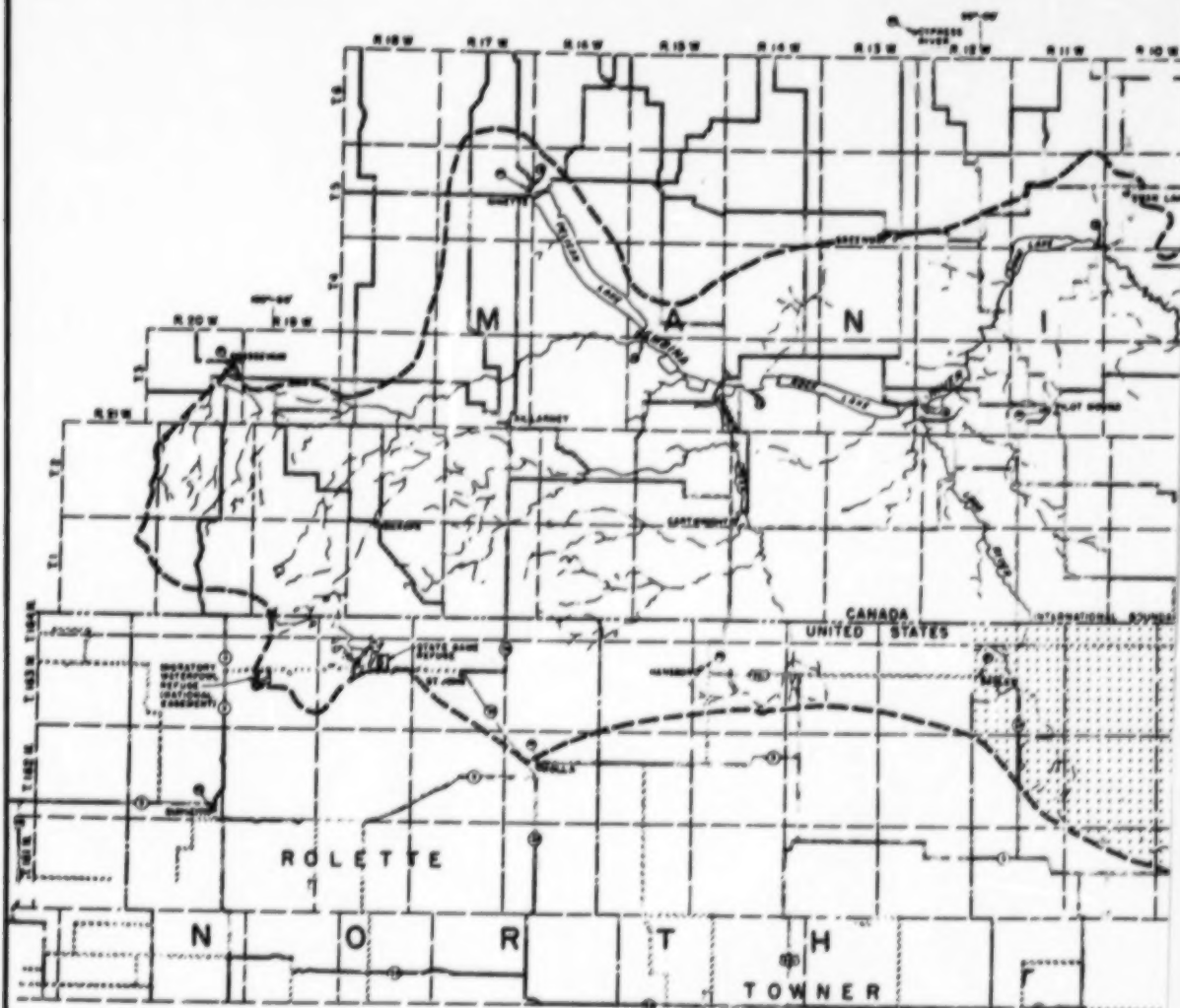
* - these municipalities are now using the Park River as a source of water

** - these figures do not meet the U. S. Public Health Service Drinking Water Standards of 1962 13/

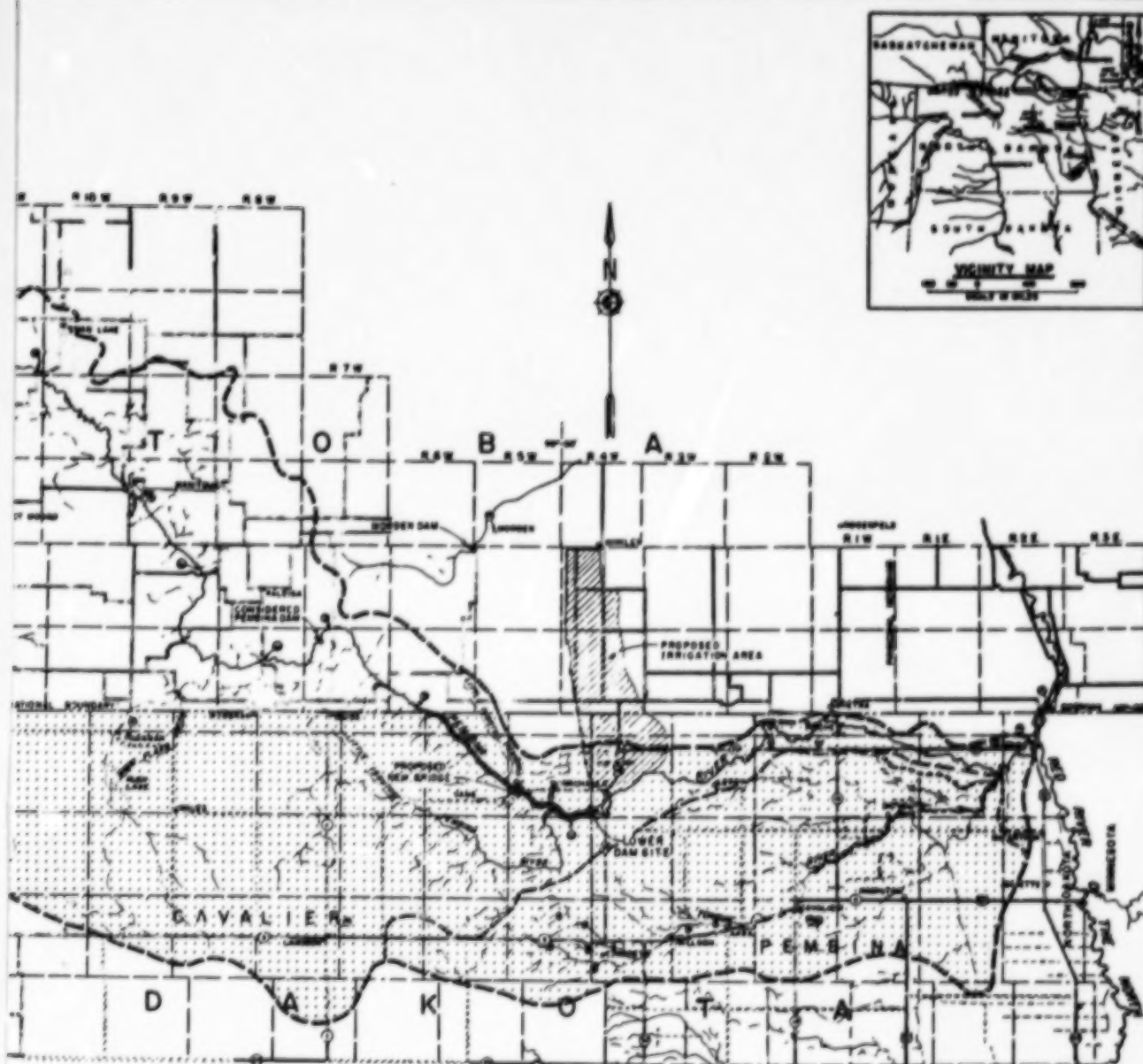
Municipal Sewage Treatment Facilities 6/Pembina River Study Area

Municipalities	1960 Population	Type Treatment	Discharge To	Population Equivale: (BOD in ppm)	
				Raw	Treated
Adams	360	Lo	South Branch Park River	330	0
Cavalier	1,423	Lo	Land	1,450	0
Drayton	940	None	Red River	910	910
Grafton	5,885	Lo	Park River	85,000E	*
Langdon	2,151	Lo	Intermittent Creek	1,760	0
Minto	640	Lo	Land	550	0
Neché	545	Lo	Pembina River	700	0
Osnabrock	289	Lo	Land	250	0
Park River	1,813	Lo	Land	15,000E	*
Pembina	625	Lo	Pembina River	515	0
Walhalla	1,432	None	Pembina River	1,100	1,100

* - Information unknown
 Lo - Oxidation lagoons or ponds
 E - Estimated
 BOD - Biochemical Oxygen Demand
 ppm - Parts per million



LEGEND
 STREAM G
 CLIMATE C
 PROPOSED
 PROPOSED
 PROPOSED
 CANADIAN
 STUDY AT



LEGEND

- STREAM GAGING STATION (U.S. GEOLOGICAL SURVEY OR CANADIAN)
- CLIMATOLOGICAL STATION (U.S. WEATHER BUREAU OR CANADIAN)
- PROPOSED PEMBINA RESERVOIR
- PROPOSED IRRIGATION CONDUIT
- PROPOSED IRRIGATION CANAL
- CANADIAN SAMPLING STATIONS
- STUDY AREA

PEMBINA RIVER BASIN MAP AND STUDY AREA

REVISED: FEBRUARY, 1963

FROM ORIGINAL BY: U.S. ARMY CORPS OF ENGINEERS
AND THE PEMBINA RIVER INTERNATIONAL
ENGINEERING COMMITTEE

DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE

REGION VI

KANSAS CITY, MISSOURI

FIGURE 1